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INTERPRETATION OF TILL GEOCHEMICAL DATA IN NOVA SCOTIA, CANADA,....

by R. G. Turner and R. R. Stea

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INTERPRETATION OF TILL GEOCHEMICAL DATA IN NOVA SCOTIA, CANADA, USING MAPPED TILL UNITS, MULTI-ELEMENT ANOMALY PATTERNS, AND THE RELATIONSHIP OF TILL CLAST GEOLOGY TO MATRIX GEOCHEMISTRY

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ABSTRACT

The significance of multi-element (Cu, Pb, Zn, Cd, Ag, Sn and W) till anomalies in selected areas of northern mainland Nova Scotia was examined by: (1) comparing local element levels for mapped till types with regional element levels calculated from a combination of all till types; (2) examining the spatial pattern of multi-element anomalies in selected study areas; and (3) assessing the inter-element associations and element-clast geology associations for each major till type. Large areas of single element anomalies were outlined using the 75th and 95th percentile contours from the regional data set. Local case studies (Wentworth Station, Scotsburn and Ohio) were selected within these regionally contoured areas.

At Wentworth Station till matrix geochemistry and clast correlations identify Cobequid Highlands granitic rocks as the host for Sn-W minerals producing till anomalies. Cassiterite has been identified in the Cobequid Highlands Massif. The Sn-W till anomalies overlying Carboniferous sedimentary rocks north of the Cobequid Highlands are related to northward glacial dispersal and/or Carboniferous paleoplacer deposition.

At Scotsburn the proximity of multi-element base metal till anomalies to known Pb-Zn and Cu-Ag mineral occurrences and primary metal associations like Pb and Zn suggest that the till anomalies are significant.

Within the Ohio study area one group of base metal till anomalies is related to a known copper belt. A second group of tungsten-base metal till anomalies may reflect an undiscovered polymetallic mineral occurrence hosted by volcanic rocks of the Antigonish Highlands. Tungsten levels are correlated with felsic volcanic clast percentages in stony tills of the area.

INTRODUCTION

The focus of this paper is to examine the significance of multi-element (Cu, Pb, Zn, Cd, Ag, Sn and W) till anomalies in selected areas of northern Nova Scotia by: (1) comparing local element levels for mapped till types with regional element levels (percentile contours calculated from a combination of all till types in the till data set; n = 941); (2) examining the spatial pattern of multi-element anomalies in selected study areas; and (3) assessing the interelement associations and element-clast geology associations for each major till type in the study areas. Two of the selected case study areas contain known mineralization (cassiterite in mafic volcanics near Wentworth Station and base metals in sedimentary rocks near Scotsburn). The third area was chosen because of unexplained tungsten and base metal till anomalies overlying volcanic rocks west of Ohio. The geochemical data are presently being compiled on six 1:100 000 scale open file maps, four of which have been released (Turner and Stea, 1987a, 1987b, 1988a, 1988b).

General Geology and Mineralization

Northern mainland Nova Scotia is separated into four physiographic regions: the Cobequid Highlands, Cumberland-Pictou Lowlands, Hants-Colchester Lowlands and

Antigonish Highlands (Fig. 1).

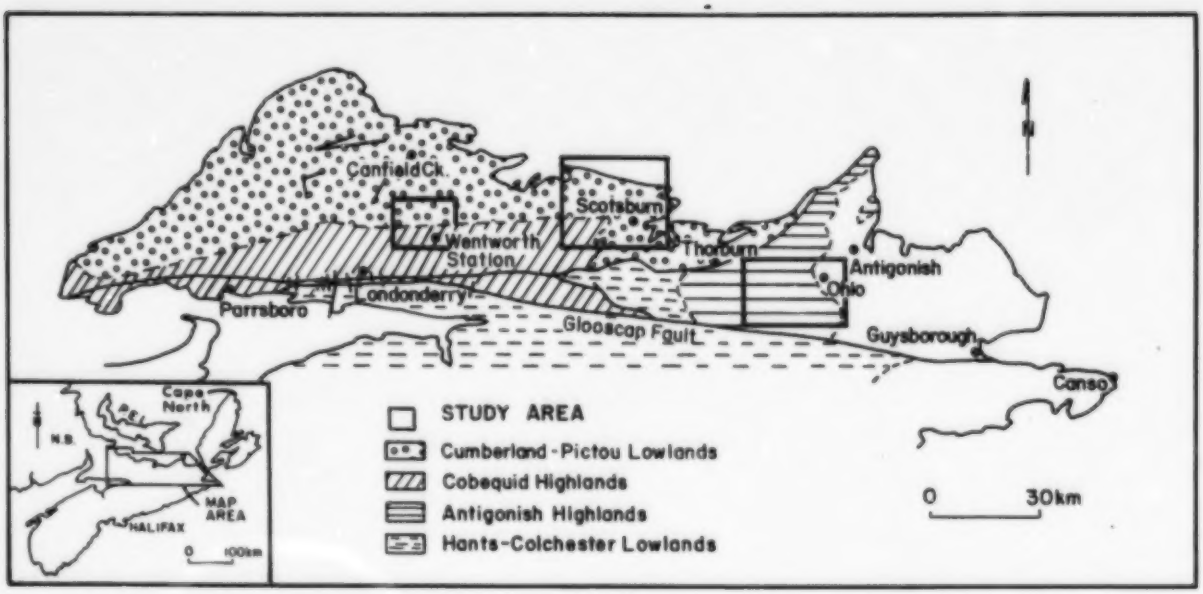


Figure 1. General physiography of northern mainland Nova Scotia and location of the Wentworth Station, Scotsburn and Ohio study areas.

The Cobequid Highlands consist of Helikian to Devono-Carboniferous rocks segregated into numerous fault blocks and separated from adjacent lowlands by the Glooscap Fault System (Donohoe and Wallace, 1982). Most of the known mineral occurrences in the Cobequid Highlands are vein type with base metal sulphides (Cu-Pb-Zn), iron carbonates and barite dominant (Donohoe, 1982). These occur in granites along the Glooscap Fault Zone and in siltstones of the Carboniferous Londonderry Formation that outcrop near the fault zone.

The Cumberland-Pictou Lowlands are underlain by Upper Carboniferous sedimentary rocks. Copper (mainly chalcocite and bornite), uranium and silver constitute most of the known mineral occurrences found in the region (Chatterjee, 1983). A few galena occurrences have been discovered recently in Pictou Group strata (Ryan, 1984).

The Hants-Colchester Lowlands are mainly composed of Carboniferous clastic and evaporitic rocks and Triassic clastic rocks. Mineral occurrences are

predominantly stratabound Mn-Fe-Cu-Pb-Ag-Ba in the Lower Carboniferous Windsor Group (Chatterjee, 1983).

The Antigonish Highlands are composed predominantly of Precambrian metavolcanic and metasedimentary rocks unconformably overlain by Lower Paleozoic strata (Murphy, 1984). Mineral occurrences include chalcopyrite, malachite, sphalerite, hematite, manganese nodules and barite (Bourque, 1979). East of the Antigonish Highlands, Windsor Group carbonates containing Cu-Pb-Zn-Ba-Ag occurrences and Devono-Carboniferous clastic sedimentary rocks locally mineralized with Fe-Cu-Ba predominate.

Quaternary Geology

Striations, till fabric, glacial landform analysis, and the dispersal of distinctive erratics indicate that northern mainland Nova Scotia has been affected by at least four major ice flows with some local piedmont and valley glaciers (Stea and Finck, 1984; Stea, 1984; Turner and Stea, 1987c).

An Early Wisconsinan(?) eastward to southeastward ice flow produced a thick, indurated, matrix-dominated till (McCarron Brook Till) that is found subcropping beneath surface tills along the Northumberland Strait coast and the north shore of Minas Basin. Its presence is not confirmed elsewhere beneath the surface till.

Surface tills were the main sample media in this regional survey. Two major surface till units, formed by two separate phases of ice flow, were sampled. Figure 2 is a cartoon depicting till formation in the Cobequid Highlands and adjacent lowlands during the last two glaciations. In much of the lowland region a surface till sheet called the Eatonville Till overlies the McCarron Brook Till (Stea et al., 1986). The Eatonville Till is characterized by a red silty matrix and a pebble fraction derived largely from Carboniferous sedimentary rocks. It is

a lodgment till formed during an extensive southward ice flow (Fig. 2; Stea and Finck, 1984; Alcock, 1984).

Stony, locally derived tills (Cobequid and Toney River Tills) overlie the Eatonville Till. The Cobequid Till was formed by northward ice flow from an ice divide over southern Nova Scotia. A sandy ablation till forms isolated patches of hummocky moraine in parts of the Cumberland - Pictou Lowlands. This till was

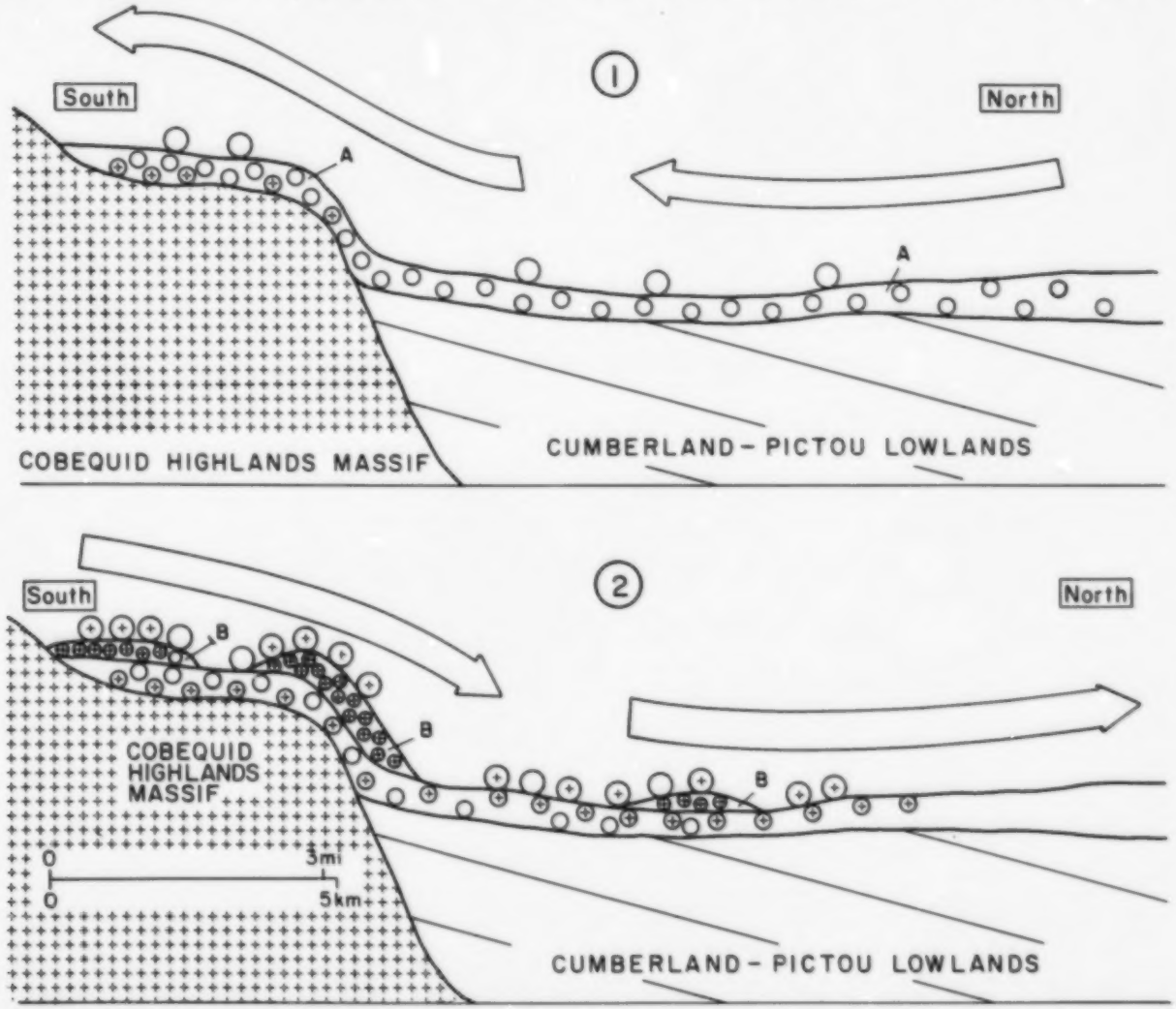


Figure 2. Diagrammatic representation of the major till-forming ice flow phases occurring in the Wentworth Station study area. (1) Southward ice flow forming the Eatonville Till (A). (2) Northward ice flow forming the stony till (B) on the highlands and trasporting Cobequid Highland erratics over the previously deposited Eatonville Till.

deposited during the northward flow as revealed by its occurrence in belts divide over southern Nova Scotia. A sandy ablation till forms isolated patches of hummocky moraine in parts of the Cumberland - Pictou Lowlands. This till was deposited during the northward flow as revealed by its occurrence in belts parallel to the inferred moraines of the northward-flowing glacier. Late-stage glaciers flowed southwestward through the Hants-Colchester Lowlands (Stea et al., 1986) and from the Antigonish Highlands (Turner and Stea, 1987c) and sporadically deposited a stony, locally-derived till similar to the Cobequid Till.

SAMPLING METHODS

During the 1982-86 field seasons 941 till samples were collected from northern mainland Nova Scotia, between Parrsboro and Canso, at an average density of 1 sample per 13 km^2 (Fig. 1). Samples were obtained from road cuts, sea cliffs and till pits at an average depth of 1.5 m below the modern solum. Sampling was concurrent with surficial mapping and sample sites were selected in areas of good till exposure.

The Size of a Glacial-Mechanical 'Halo' or Exploration Target

Till samples represent an area of bedrock 'sampled' by a glacier. The size of a secondary geochemical 'halo' or exploration target derived from a mineralized bedrock area is variable depending on ice flow direction and glacial dispersal, the dynamics of the glacier and resulting till facies, the initial abundance of the element analyzed and size of the mineralized outcrop area, and post-glacial hydromorphic dispersion. Recent work on glacial dispersal in Nova Scotia (Stea et al., 1988) has shown that glacial-mechanical haloes can be quite large given the

complex glacial history of the region. The composition of a single till sample can reflect bedrock sources along several glacier flow paths.

Figure 3 illustrates the net effect of glacial dispersal produced during four ice flow phases. It shows the dispersal pattern of distinctive, boulder-sized hornblende diorite (appinite) erratics from the Eden Lake Complex. The Garden of Eden area has been affected by four major ice flow events. The relative ages of these ice flows have been recorded at two striation sites near Eden Lake. A

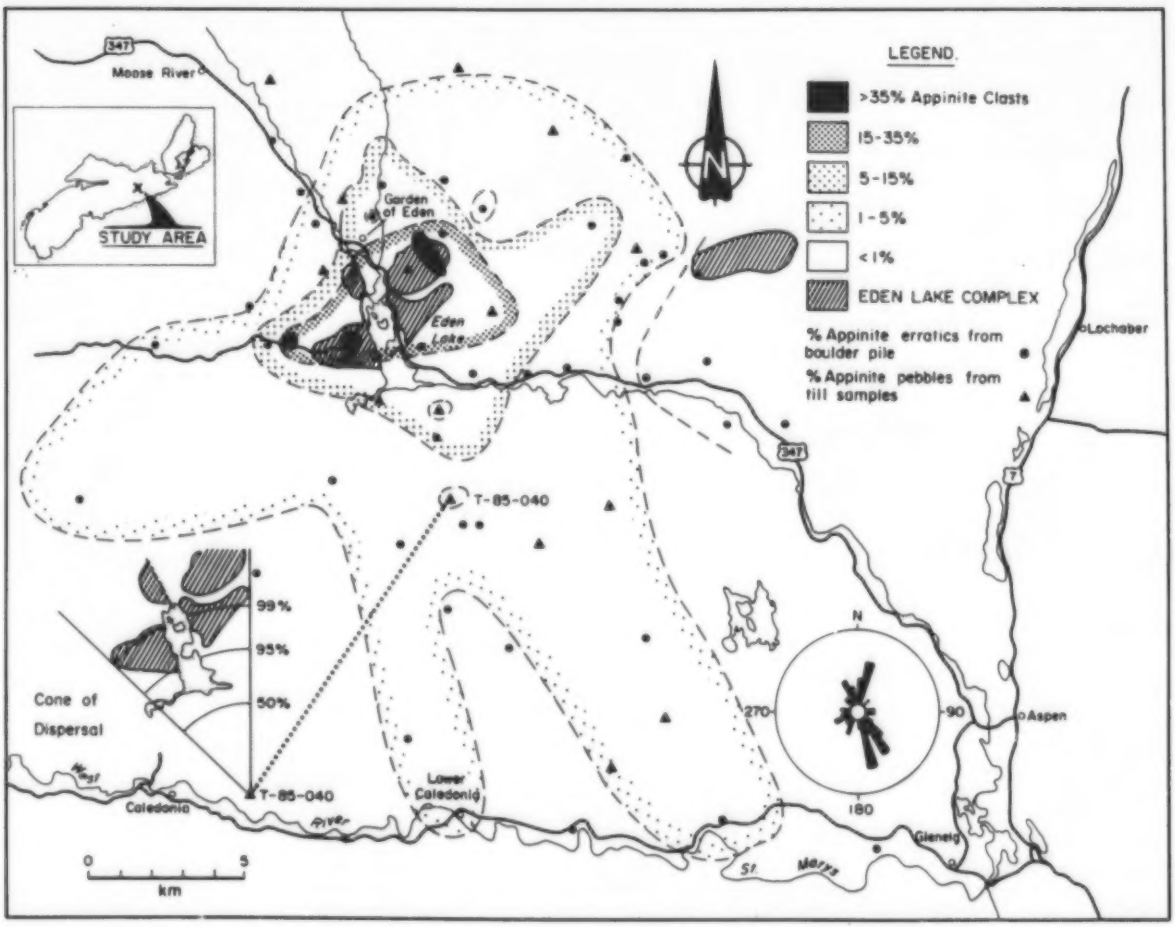


Figure 3. Plot of the dispersal of boulder sized appinite clasts from the Eden Lake Complex based on counts from boulder piles and till sections. Rose diagram of striation trends in the 1:50 000 map sheet region. The cone of dispersal represents the source area for clasts contained in an Eatonville Till sample situated down-ice (south) of the Eden Lake Complex. The half distance is about 3 km.

summary of these flows from oldest to youngest is: (1) N140°E, (2) N165°E, (3) N005°E and (4) N220°E. The 1% to 5% contour of appinite clasts indicates a four-directional trend similar to the striation directions. These are: (1) two long southeast-trending, lobate dispersal trains (140°-160° and 170°-180°); (2) a broadnorth-northeast trending fan (350°-080°); and (3) a broad southwest-trending fan (225°-250°).

The two long southeastward-trending dispersal trains are the dominant patterns. The maximum extent of the 140°-160° dispersal lobe is not known as it intersects with dispersal from the appinite complex near Black Brook Lake. However, the 5% to 15% contour of appinite erratics extends about 5 km in this general direction. The extent of the 170°-180° dispersal train for the 1% to 5% contour of appinite clasts is between 15 and 20 km. Dispersal patterns trending north-northeast and southwest form broad fans or plumes. This may be the result of changes in the ice direction as indicated by the fanning of striations (Fig. 3). The 1% to 5% contour of appinite erratics extends 7-8 km north-northeast and about 10 km southwest. A single appinite boulder was found 40 km southwest of the Eden Lake area. Two areas with greater than 40% appinite clasts are located directly over the Eden Lake Complex. These areas may be coincident with zones of appinite within the complex.

Figure 3 (cone of dispersal) illustrates dispersal of clast lithologies contained in an Eatonville Till sample situated about 5 km southeast of the Eden Lake Complex within the southeastward dispersal train. This sample contains about 2% hornblende syenite clasts derived from the Eden Lake Complex. Using methods described by Salonen (1986) transport distances were calculated, on the basis of clast content, for several Eatonville Till samples in this area. The half distance is about 3 km (Fig. 3). This is the distance over which the proportion

of a new rock type in the till increases from 0 to 50% away from a bedrock contact (Peltoniemi, 1985). One to 5% of the clasts (clasts representing the far-travelled component, like the hornblende syenite clasts) are transported >4 km (Fig. 3). This parameter is a measure of the sampling area of the till. Although the source area is shown as a cone-shaped area in the figure (the possible source area is based on the extent of distinctive up-ice lithologies), the till sample in this case represents a channel sample of a nearly linear path of bedrock up to 6 km from the Eden Lake Complex.

In the case of till samples located within other dispersal fans a vector of transport corresponding to the dispersal direction is added. Tills characterized by a dominance of clast over matrix modes (stony tills) generally have half distances of <1 km (Stea et al., 1988). Glacial-mechanical haloes within these stony till sheets are relatively restricted compared to haloes within the Eatonville Till.

Till matrix geochemistry is related to the clast component of a till (Stea et al., 1985; Saarnisto and Taipale, 1985). Mineralized rock debris contributing to the clast component of a till should be reflected as anomalous element levels within till samples in these glacial sampling channels. Between 150-250 pebbles (>4.0 mm) were identified from each till sample. The relationships between clast lithology percentages and element levels in each study area were assessed using Spearman rank correlation coefficients (Tables 2, 3 and 4). The purpose of this method was to identify possible bedrock sources for the till anomalies.

ANALYTICAL METHODS

The clay (<0.002 mm) fraction of till samples was analyzed for Cu, Pb, Zn, Cd, Ag, Ni, Co, Fe, Mn, Ca, Mg and Mo using atomic absorption spectrophotometry, As

using colorimetry, and U using fluorometry. Analyses were completed by Bondar-Clegg and Company Limited, Ottawa. The fine sand fraction (0.06-0.3 mm) heavy mineral separate (specific gravity >2.95) was analyzed for Sn and W using iodide fusion and colorimetry, respectively.

Selected heavy mineral samples were examined by scanning electron microscope (S.E.M.) at the Atlantic Coal Institute, Nova Scotia, to determine the nature of minerals producing the anomalies. Heavy mineral grains were mounted on carbon stubs and carbon coated. Samples were first manually searched and then analyzed using an automated heavy mineral particle recognition program.

DATA MANIPULATION

The Sn and W heavy mineral data were weighted using Toverud's (1982) formula before threshold levels were calculated. The weighting procedure normalizes the amount of heavy minerals in a sample with respect to the total weight of fine sand fraction used in the heavy liquid separation. The weighted value is equal to the weight of the heavy mineral separate divided by the weight of the fine sand fraction and multiplied by the analytical value (Toverud, 1982).

The Cu, Pb, Zn, Cd, Ag, Sn and W data were contoured using percentiles calculated from the cumulative frequency distribution of the entire till data set of 941 samples. The regional threshold value was arbitrarily set at the 95th percentile of the contoured data (Table 1). Large areas of single-element anomalies were outlined using these regional contours and many contained coincident anomalies in related elements (for example enrichment in Cu, Pb, Zn, Cd and Ag occurs over the Scotsburn Anticline, as discussed later). Local case studies (Wentworth Station, Scotsburn and Ohio) were selected from the regional contour maps. In these local study areas threshold levels (95th percentile) were

Table 1. Analytical data; all values are in ppm (Sn and W data are weighted).

REGIONAL DATA SET (n = 941)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.05	46	31	120	.2	.11	.07
95th PERCENTILE	.30	130	120	330	2.9	.65	.28

STUDY AREA DATA SETS

WENTWORTH STATION (Eatonville Till) (n = 32)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.12	45	47	123	1.3	.25	.13
95th PERCENTILE	.18	109	86	227	2.7	.51	.21
STANDARD DEVIATION	.22	35	22	57	4.3	.22	.11

WENTWORTH STATION (Cobequid Till) (n = 7)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.06	83	76	224	-	.58	.46
95th PERCENTILE	.10	103	89	248	-	.89	1.32
STANDARD DEVIATION	.02	18	12	20	-	.21	.47

WENTWORTH STATION (Regolith) (n = 7)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.12	43	72	217	1.0	.55	.27
95th PERCENTILE	.39	90	150	405	1.6	1.22	.99
STANDARD DEVIATION	.13	25	47	128	.7	.41	.32

SCOTSBURN (Eatonville Till) (n = 66)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.11	75	64	204	.9	.10	.07
95th PERCENTILE	.50	128	96	540	3.6	.24	.19
STANDARD DEVIATION	.19	194	143	259	1.4	.08	.08

SCOTSBURN (Toney River Till) (n = 13)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.05	61	45	223	2.0	.10	.07
95th PERCENTILE	.10	144	104	680	7.4	.74	.15
STANDARD DEVIATION	.01	41	29	204	2.1	.20	.04

OHIO (Eatonville Till) (n = 27)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.10	55	31	169	.8	.24	.13
95th PERCENTILE	.31	101	52	391	1.1	.89	.29
STANDARD DEVIATION	.12	20	19	92	3.4	.26	.08

OHIO (Stony,Grey Till) (n = 29)

	Ag	Cu	Pb	Zn	Cd	Sn	W
MEAN	.18	101	36	217	.3	.26	.26
95th PERCENTILE	.60	240	92	880	1.3	.70	.57
STANDARD DEVIATION	.22	61	30	231	.4	.18	.35

calculated for each major till type using the cumulative frequency distribution (Table 1) because element levels vary significantly in different till types (Stea et al., 1986).

Geochemical data in the selected study areas show a tendency toward a continuous range of values with positive skewness (Fig. 4). In many cases the natural separation between background and anomalous populations is not obvious. All methods of threshold determination are based on statistical parameters, many of which assume normality of data. The 95th percentile threshold level is an arbitrary separation of a data set and is used because it is nonparametric. Some significant element levels, however, may be ignored by the 95th percentile threshold method.

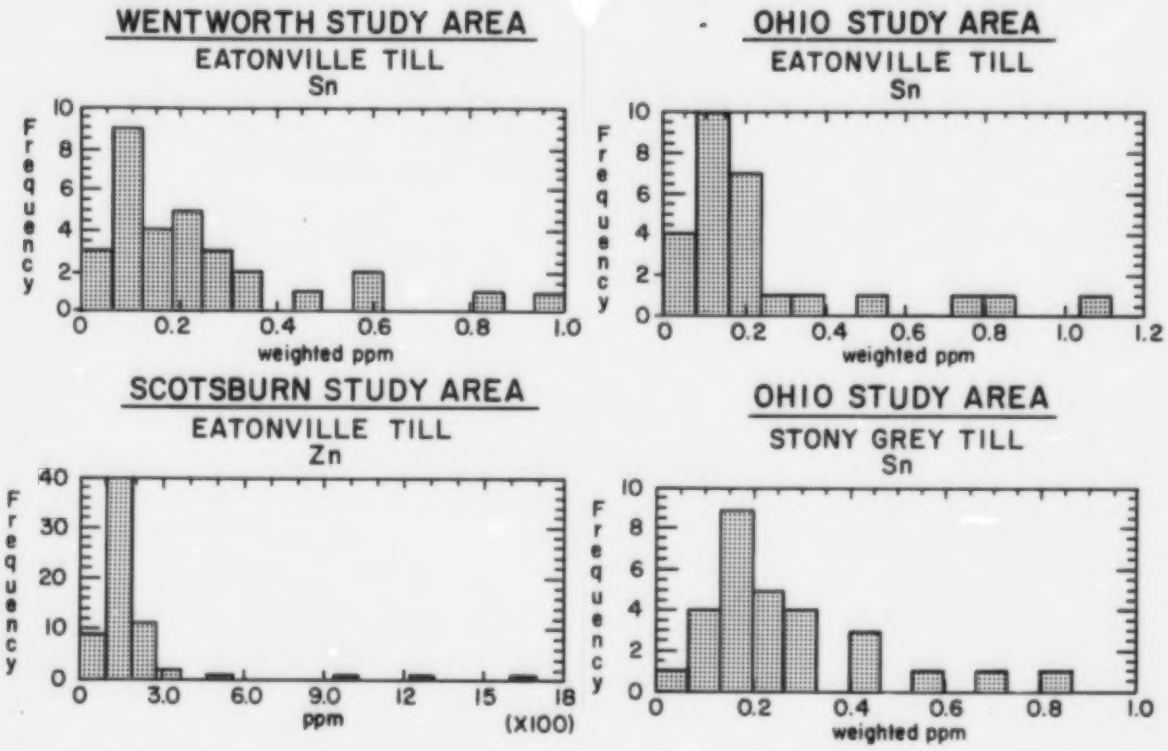


Figure 4. Frequency histogram examples of till geochemical data from the study areas.

In this study three methods were used to assess the significance of till geochemical anomalies: (1) classifying major till types (based on lithological and textural parameters) before threshold calculation; (2) examining the significance of anomalies using inter-element correlations and relating the till geochemistry to bedrock geology; and (3) using a multi-element approach which compensates for below-threshold significant element levels by revealing anomalies in associated elements that are related to mineralization.

Multi-element anomalies in the study areas were synthesized using anomaly values (Overstreet et al., 1978). Anomaly ratios were calculated by dividing the anomalous value of an element in a sample from a local study area by the threshold value for that element, as determined by the thresholds for each till type. The

anomaly value is the sum of the anomaly ratios for each element in a sample. These data are presented as anomaly association maps for each study area.

CASE STUDY AREAS

Detailed analyses (including geology, mineral occurrences, element levels, till geochemical patterns, and inter-element and element-clast associations) for each study area are described in the following sections. The local case study areas at Wentworth Station and Scotsburn are areas of known mineralization. Although base metals hosted by Devono-Carboniferous rocks are well known in the Ohio study area, a new area of base metal and tungsten mineral potential is examined in metavolcanic rocks west of Ohio.

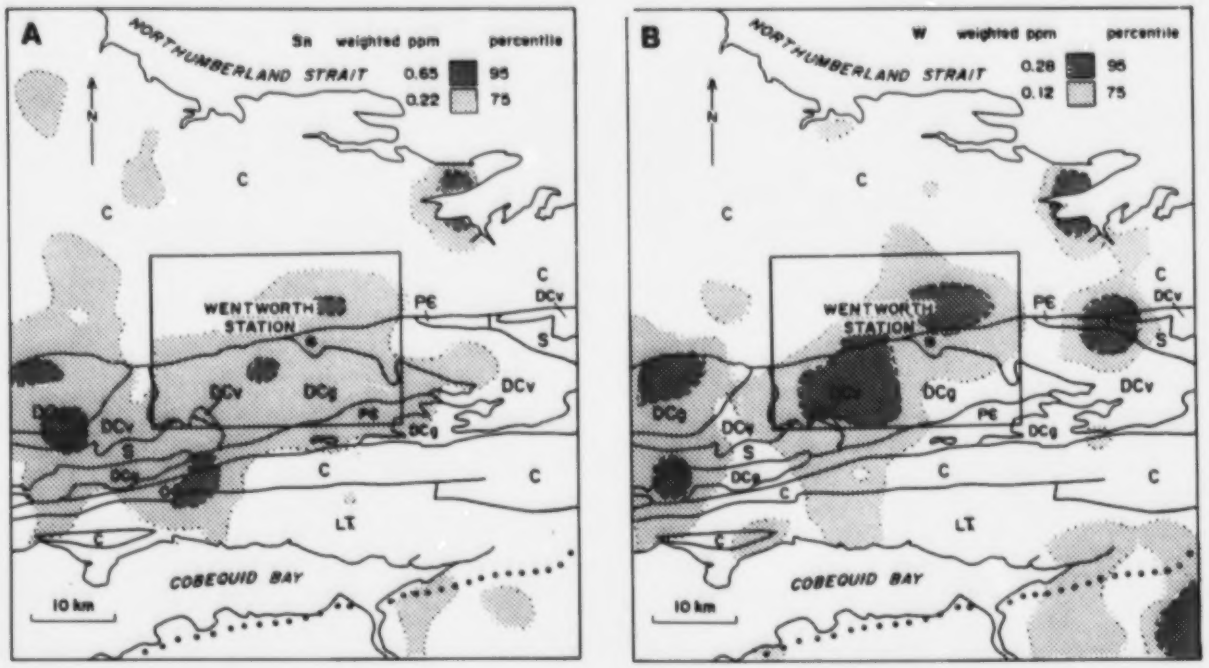
Wentworth Station

The Wentworth Station study area (about 670 km^2) encompasses parts of the Cobequid Highlands and Cumberland Basin, with the village of Wentworth Station located near the centre (Fig. 5). Most of the area is underlain by Carboniferous granite. Devonian (Byers Brook Formation) volcanics flank the granite and Carboniferous sedimentary rocks lie north of the Cobequid Highlands (Figs. 5 and 6). Cassiterite was identified by Chatterjee (1984) in drill core from alkali basalts of the Byers Brook Formation near Debert Lake. The Eatonville Till overlies both the Cumberland Basin and the Cobequid Highlands whereas the Cobequid Till is found predominantly in highland areas (Fig. 2). Small areas of exposed, weathered bedrock (regolith) were also sampled.

The regional contour plots (Fig. 5) identify local Sn-W anomalies in the surface till overlying the Devonian Byers Brook Formation volcanics, Carboniferous

granite, and Carboniferous sedimentary rocks north of Wentworth Station. The 75th percentile for Sn and W forms a halo surrounding these anomalies and extends northward over the Cumberland Basin (Fig. 5).

Local threshold levels for this area are similar to the regional levels (Table 1). The Eatonville Till has slightly lower Sn-W threshold levels compared



GEOLOGY

LT LATE TRIASSIC
clastic sedimentary rocks

C CARBONIFEROUS
clastic and evaporitic sedimentary rocks

DCv DEVONO-CARBONIFEROUS
mixed volcanic and clastic sedimentary rocks
(including Byers Brook Formation)

DCg DEVONO-CARBONIFEROUS
granitoid rock

S SILURIAN
metavolcanic and metaclastic rocks

PE PRECAMBRIAN
basement complex
undifferentiated schists and gneisses

WENTWORTH STATION STUDY AREA

Figure 5. Regional contour plots of weighted (A) Sn and (B) W data. Percentiles are derived from the total data set (n = 941; Table 1). Regional geology and the Wentworth Station study area are also illustrated.

to regional levels. The Sn-W threshold levels observed in the small Cobequid Till and regolith data sets (n = 7) are controlled by several high values that skew the cumulative frequency distribution and increase the mean values (Table 1).

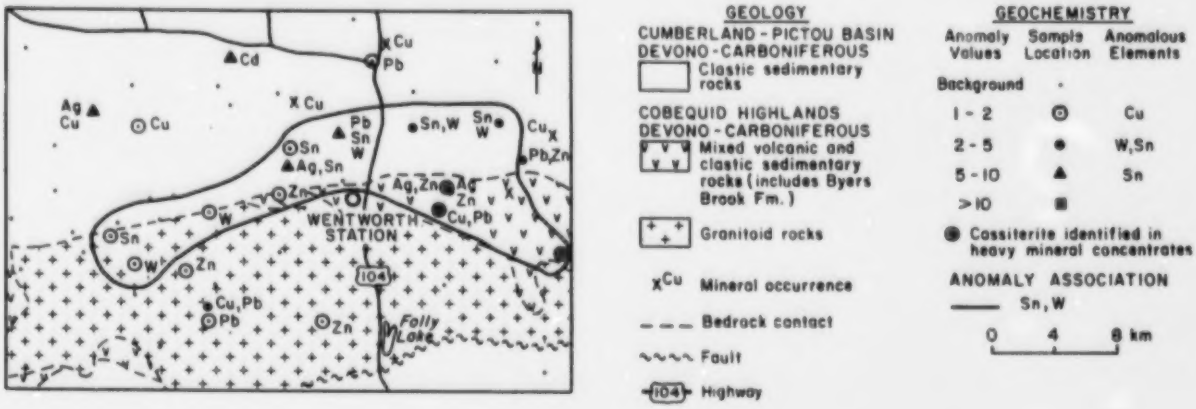


Figure 6. Anomaly association map of the Wentworth Station study area.

Elevated mean or background values of Sn-W are characteristic of the regional Cobequid Till data set (Sn = 0.44 ppm, W = 0.25 ppm; n = 42). Elevated levels of Sn and W in Cobequid Till samples may be a result of natural or nonsignificant enrichment of Sn and W in the igneous rocks of the Cobequid Highlands or a reflection of glacial dilution of significant anomalies from undiscovered mineral occurrences. This problem cannot be resolved at a regional scale of sampling so it is prudent to highlight only the upper 5%.

The Sn-W anomaly association outlines a narrow belt of anomalies parallel to the contact between the Cobequid Highland Massif and the Cumberland Basin extending northward over the basin (Fig. 6). Weathered cassiterite grains (Plate 1) were observed (by S.E.M.) in heavy mineral concentrates from three till samples overlying the Byers Brook Formation volcanics near the granite contact. Rogers (personal communication, 1987) has identified cassiterite in stream sediments from this area. The Sn-W anomalies identified in till overlying the Carboniferous strata may result from two possible sources: (1) northward glacial

dispersal and comminution of igneous rocks derived from the Cobequids Highlands and/or (2) Carboniferous paleoplacers.

Plate 1. Scanning electron microscope photomicrograph of a cassiterite grain identified in a heavy mineral concentrate from a Cobequid Till sample collected near Wentworth Station.

Northward ice flow deposited Cobequid Highlands erratics over the previously deposited Eatonville Till (Fig. 2; Stea et al., 1986). Both the regional 75th percentile pattern and the anomaly association map show a northward trend from the highlands (Figs. 5 and 6). Spearman rank correlation coefficients comparing element levels and pebble lithology percentages for Eatonville Till samples collected in the Wentworth Station study area show a positive correlation of Sn and W levels with granitic clast percentages (0.63 and 0.43 respectively; Table 2a). A similar response is noted in the regolith samples where Sn and W levels are again positively correlated with granitic clast percentage (0.76 and 0.81 respectively; Table 2b). Tin levels are negatively correlated with grey sedimentary clast percentages in Cobequid Till samples (-0.86). These correlations imply that, at least on the highlands, granitic rocks host the Sn-W minerals.

Nonsignificant correlations exist between Sn-W levels and igneous and sedimentary clast percentages for Eatonville Till samples collected over the

Table 2a. Spearman rank correlation coefficients for Eatonville Till samples (n=32) in the Wentworth Station study area.

SPEARMAN RANK CORRELATION COEFFICIENTS

WENTWORTH STATION (Eatonville Till)
(n = 32)

	Ag	Cu	Pb	Zn	Cd	Ni	Co	Fe	Mn	Ca	Mg	As	Mo	U	Sn	W
Ag	1.0	-	-	-	-.43	-	-	.40	-	-	-	-	-	-	-	-
Cu		1.0	-	-	.33	.33	.52	-	-	-	.42	-	-	-	-	-
Pb			1.0	.66	-	-	-	.52	-	.39	-	-	-	-	.35	.50
Zn				1.0	-	.55	.38	.44	-	.45	.62	-	-.32	-	-	.34
Cd					1.0	-	-	-.46	.57	-	-	.52	-	-	-.53	-
Ni						1.0	.79	-	-	.34	.73	.44	-	-	-	-
Co							1.0	-	-	-	.69	-	-	-	-	-
Fe								1.0	-	.30	-	-	-	.44	.52	-
Mn									1.0	-	.41	.57	-	-	-.48	-
Ca										1.0	.35	-	-.49	-	-	-
Mg											1.0	.31	-	-	-	-
As												1.0	-	-	-.38	-
Mo													1.0	-	-	-
U														1.0	-	-
Sn															1.0	.65
W																1.0

CRITICAL VALUES OF p:
95% CONFIDENCE > .31
99% CONFIDENCE > .43

CLAST LITHOLOGY AND CHEMISTRY CORRELATIONS

Red Sedimentary clasts	- Cu	(-.50)	Granite clasts	- Pb	(.46)
	- Mn	(.32)		- Cd	(-.51)
Grey Sedimentary clasts	- Cd	(.40)		- Fe	(.73)
	- Fe	(-.52)		- As	(-.45)
	- As	(.34)		- Sn	(.63)
Metamorphic clasts	- Cu	(.52)		- W	(.43)
	- U	(.39)			
Volcanic clasts	- Cu	(.30)			
	- U	(-.36)			

Cumberland-Pictou Lowlands north of the Cobequid Highlands Massif (n = 296). The Eatonville Till overlying the lowlands generally has low Sn-W levels and corresponding low igneous clast percentages resulting in background noise. This background noise masks any significant correlations between anomalous Sn-W levels and igneous clast percentages. However, these nonsignificant correlations do not prove or disprove the possibility of Carboniferous paleoplacer sources.

Evidence to suggest that some of the Sn-W anomalies are derived from Carboniferous paleoplacers includes: (1) north-trending paleochannels found in Carboniferous sedimentary rocks are composed of detrital material derived from the Cobequid Highlands Massif and (2) cassiterite and wolframite mineral grains have

been identified in sandstones that were partially derived from the Cobequid Highlands (Ryan et al., 1988).

Table 2b. Spearman rank correlation coefficients for Cobequid Till (n=7) and regolith (n=7) samples in the Wentworth Station study area.

SPEARMAN RANK CORRELATION COEFFICIENTS

WENTWORTH STATION (Cobequid Till, n = 7)
(Regolith, n = 7)

	Ag	Cu	Pb	Zn	Cd	Ni	Co	Fe	Mn	Ca	Mg	As	Mo	U	Sn	W
Ag	1.0	-	.76	.80	-	-	-	-	-	-	-	.76	-	-	-	.79*
Cu		1.0	.75	-	-	-	.84	-	-	-	-	-	-	-	-	-
Pb			1.0	.79	-	.79*	-	-	-	-	-	-	-	-	-	-
Zn				1.0	-	-	-	-	-	-	-	.86	-	-	-	-
Cd					1.0	-	-	-	-	-	-	-	-	-	-	-
Ni						1.0	-	-	-	-	.80	-	-	-	-	-
Co							1.0	.82	-	-	.98*	.73	-	-	-	-
Fe								1.0	-	-	-	-	-	-	-	-
Mn									1.0	-	-	-	-	-	-	-
Ca										1.0	-	-	-	.83	-	-
Mg											1.0	-	-	-	-	-
As												1.0	-	-	.74	-
Mo													1.0	-	-	-
U														1.0	-	-
Sn															1.0	-
W																1.0

CRITICAL VALUES OF p:
95% CONFIDENCE > .71
99% CONFIDENCE > .89

* Cobequid Till Correlations

CLAST LITHOLOGY AND CHEMISTRY CORRELATIONS

Cobequid Till:

Grey Sedimentary clasts	- Sn	(-.86)	Granite clasts - Hf (-.90)
Metamorphic clasts	- As	(-.90)	- Ca (.71)
	- Co	(.72)	
Volcanic clasts	- Pb	(-.77)	
	- Ni	(-.95)	

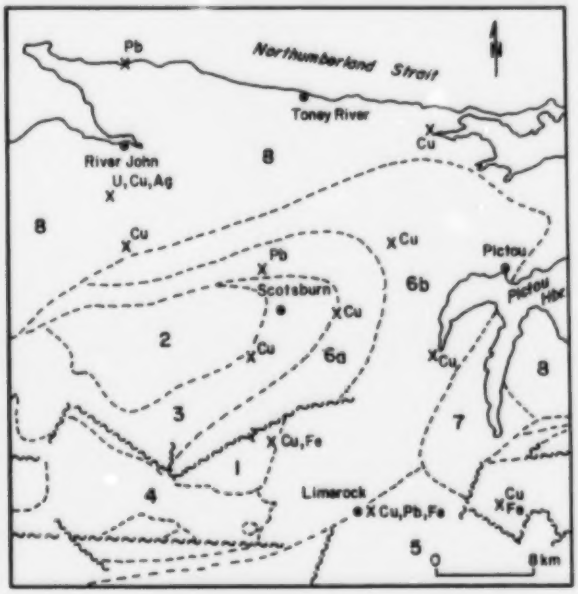
Regolith:

Grey Sedimentary clasts	- Mn	(-.74)	Granite clasts - Sn (.76)
Metamorphic clasts	- Fe	(.71)	- W (.81)
Volcanic clasts	- Ag	(.76)	- Co (-.75)
	- Pb	(.89)	

Tin levels (heavy mineral separate) are negatively correlated with Cd (-0.53), Mn (-0.48) and As (-0.38) and positively correlated with Fe (0.52) in the clay fraction (Table 2a). Since Fe is also strongly correlated with granite clasts (0.73) the Fe-Sn correlation may be coincidental. On visual inspection, Eatonville Till samples with abundant granitic debris tend to be sandier and more susceptible to surface weathering, hence having higher Fe levels in the clay fraction.

Scotsburn

The Scotsburn study area (about 1300 km^2) encompasses the Scotsburn Anticline. The eastern end of the Cobequid Highlands forms the core of this anticline. The core is flanked by Carboniferous sedimentary rocks including Millsville Formation conglomerate and sandstone, Boss Point Formation grey sandstone, siltstone and calcareous pebble conglomerate and Pictou Group sandstone (Fig. 7).



Carboniferous

8 Pictou Group
red and grey sandstone, siltstone, shale and conglomerate

7 New Glasgow Formation
conglomerate and wacke

6b Boss Point Formation
arenite, siltstone, shale, conglomerate and mudstone

6a Millsville Formation
conglomerate, sandstone, wacke and siltstone

5 Undivided Canso Group
wacke, siltstone, conglomerate and shale

Devono-Carboniferous

4 granitoid rocks

Devonian

3 Falls Formation
red conglomerate, wacke and siltstone

2 Diamond Brook Formation
basalt, siltstone and wacke

Silurian

1 Earltown Formation
siltstone, wacke, rhyolite, basalt, and felsic tuff

X Cu, Ag Mineral Occurrences

Figure 7. General geology and mineral occurrences of the Scotsburn study area.

Solution front stratiform Cu-Ag occurrences are present in the Boss Point Formation (Fig. 7; Stea et al., 1986). Copper occurrences are also present at the contact of Boss Point Formation sediments and Millsville Formation conglomerate (Fig. 7; Chatterjee, 1983). Minor galena and oxidized zinc mineralization occurs throughout the area primarily in the calcareous pebble conglomerate facies of the Boss Point Formation (McCulloch, 1984).

Eatonville Till constitutes the surface till sheet over the Scotsburn Anticline. It has a dual provenance, from the Cobequid Highlands and the Cumberland Basin. Glaciofluvial gravels and the Toney River Till were deposited after the Eatonville Till (Fig. 8). The Toney River Till is a greyish-brown, sandy, stony till composed predominantly of Carboniferous sedimentary clasts.

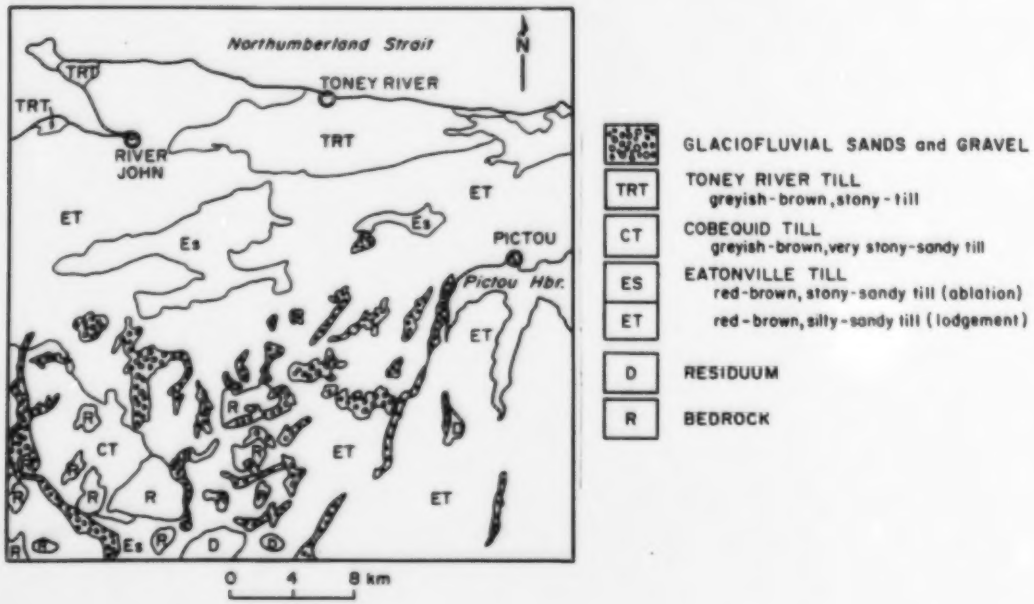


Figure 8. Surficial geology of the Scotsburn study area.

The regional 95th percentile contours identify surface till anomalies of Cu-Pb-Zn-Cd-Ag generally occurring at the bedrock contacts of the Millsville and Boss Point Formations and the Pictou Group (Fig. 9). The mean or background

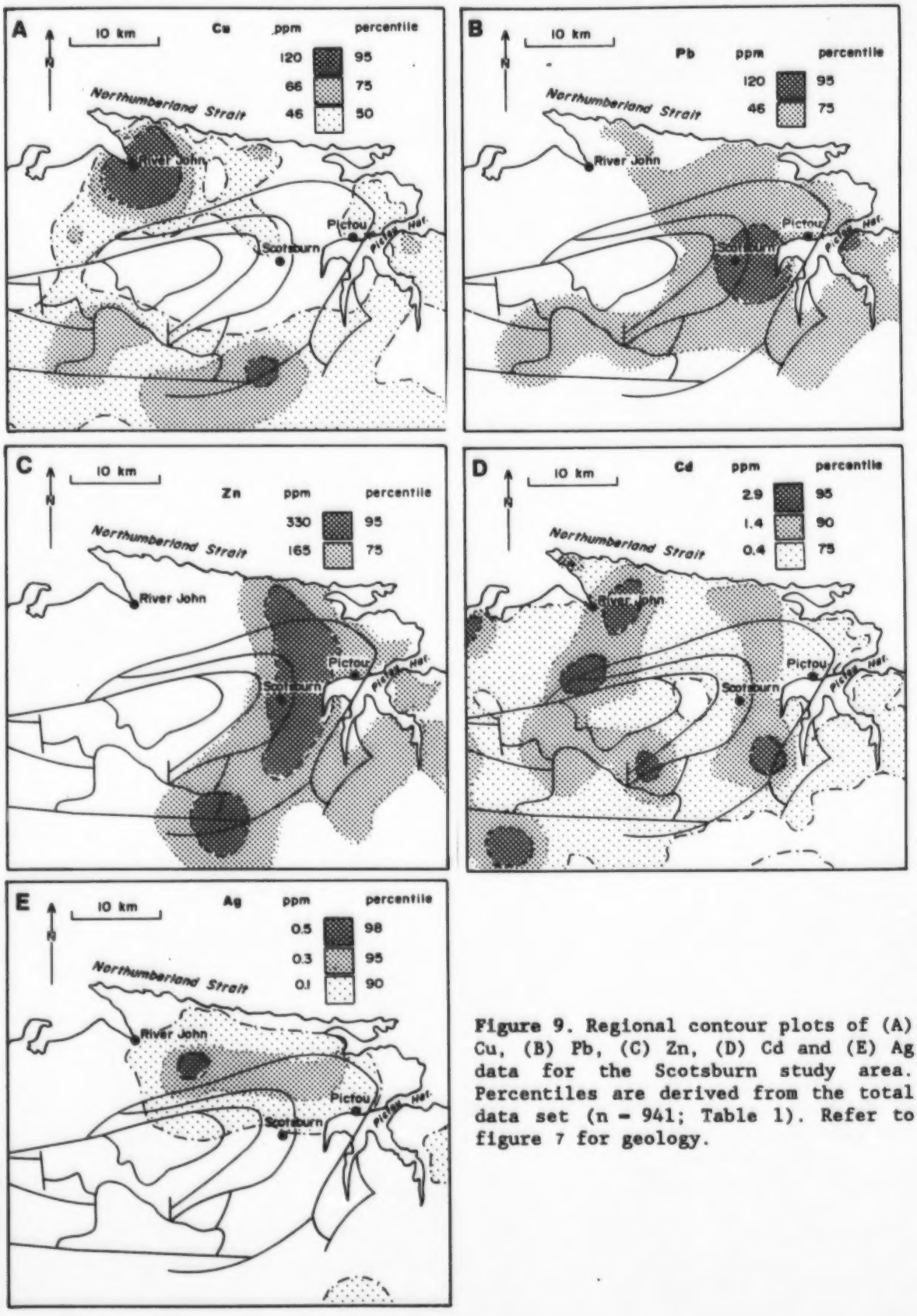


Figure 9. Regional contour plots of (A) Cu, (B) Pb, (C) Zn, (D) Cd and (E) Ag data for the Scotsburn study area. Percentiles are derived from the total data set (n = 941; Table 1). Refer to figure 7 for geology.

levels are similar for the Eatonville and Toney River Tills. Mean levels of Cu, Pb, Zn and Cd in both till types and Ag in the Eatonville Till are elevated compared to regional levels (Table 1). The higher background levels for theseelements in till may reflect the numerous base metal mineral occurrences present in the underlying bedrock.

Local threshold levels differ between the Toney River Till, Eatonville Till, and the regional till data set. The Toney River Till has higher threshold levels of Cu, Zn, Cd and Sn than both the Eatonville Till and the regional data set, and Ag levels are lower than in the Eatonville Till (Table 1). Threshold levels of Ag, Zn and Cd are greater in the Eatonville Till compared to the regional threshold levels. The Toney River Till has a sandy matrix and its clay fraction is enriched in authigenic, weathering-related sesquioxides which may increase threshold levels by scavenging processes.

The anomaly association map based on local thresholds refines the broad patterns of anomalous element levels derived by the 95th percentile contours of the entire till data set (Figs. 9 and 10). Elevated base metal element levels in

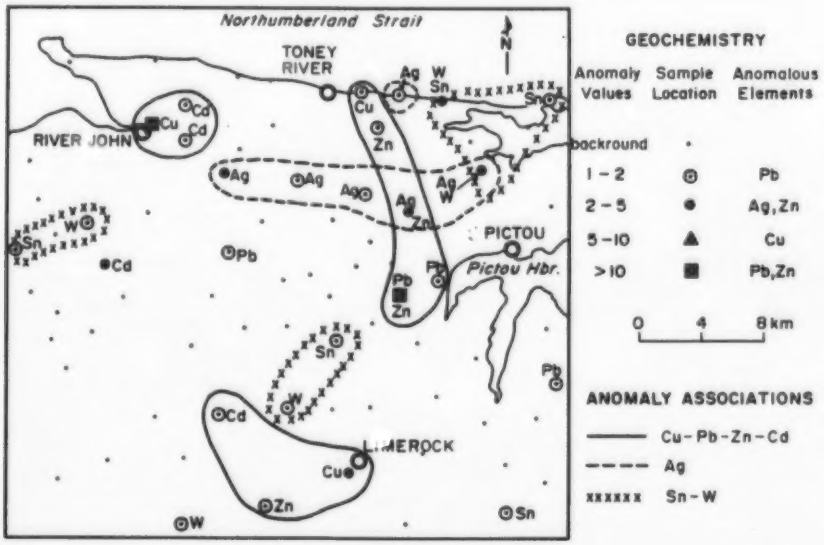


Figure 10. Anomaly association map of the Scotsburn study area.

tills overlying the Scotsburn area are probably related to the area's numerous mineral occurrences (Fig. 7). More information can be gained from the multi-element map by identifying anomalous element associations that may be indicative of mineralization. Till samples with the highest Pb-Zn anomalies occur near the contact of the Boss Point Formation sediments and the Millsville Formation conglomerate. These anomalies may be related to Boss Point Formation mineralization described by McCulloch (1984). The strong correlation of Zn levels to grey sedimentary clast percentages (0.91) in the Toney River Till (Table 3a) suggests that the Zn anomalies are related to the Boss Point Formation.

Table 3a. Spearman rank correlation coefficients for Eatonville Till samples (n=66) in the Scotsburn study area.

SPEARMAN RANK CORRELATION COEFFICIENTS

SCOTSBURN (Toney River Till)
(n = 13)

	Ag	Cu	Pb	Zn	Cd	Ni	Co	Fe	Mn	Ca	Mg	As	Mo	U	Sn	W
Ag	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cu		1.0	-	-	-	-	-	-	.60	-	-	-	-	-	-	-
Pb			1.0	-	.52	-	-	-	-	-	-	-.52	-	-	-	-
Zn				1.0	.55	.54	-	-	-	-	.64	-	-	-	-	-
Cd					1.0	-	-	-	-	-	-	-	-	-	-	-
Ni						1.0	.56	.68	-	-	-	-	-	-	-	-.65
Co							1.0	-	-	-	-	-	-	-	-	-
Fe								1.0	-	-	-	-	-	-	-	-.62
Mn									1.0	-	-	-	-	.50	-	-
Ca										1.0	-	-	-	-	-	-
Mg											1.0	-	-	-	-	-
As												1.0	-	-	-	-
Mo													1.0	-	-	-
U														1.0	-	-
Sn															1.0	.69
W																1.0

CRITICAL VALUES OF p:
95% CONFIDENCE > .51
99% CONFIDENCE > .71

CLAST LITHOLOGY AND CHEMISTRY CORRELATIONS

Red Sedimentary clasts - Zn (-.62)
- Ni (-.75)
- Co (-.69)
- Fe (-.50)

Grey Sedimentary clasts - Zn (.91)
- Mg (.73)
- U (-.59)

Granite clasts - Sn (.64)

Metamorphic clasts - Mg (-.69)

Zinc levels are weakly correlated with Fe levels (0.39) in the Eatonville Till and scavenging by Fe may be creating false Zn anomalies. Lead levels are also positively correlated with Zn and Cd levels in the Eatonville Till (0.51 and 0.44 respectively; Table 3b). The proximity to known Pb-Zn mineral occurrences and the primary metal association between Pb and Zn suggests that these anomalies

Table 3b. Spearman rank correlation coefficients for Toney River Till samples (n=13) in the Scotsburn study area.

SPEARMAN RANK CORRELATION COEFFICIENTS

SCOTSBURN (Eatonville Till)
(n = 66)

	Ag	Cu	Pb	Zn	Cd	Ni	Co	Fe	Mn	Ca	Mg	As	Mo	U	Sn	W
Ag	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cu		1.0	-	-	-	-	.34	-	-	-	-	-	-	-	-	-
Pb			1.0	.51	.44	-	-	-	-	-	-	-	.34	-	-	-
Zn				1.0	-	-	-	.39	-	-	-	-	-	-	-	-
Cd					1.0	-	-	-	-	-	-	-	-	-	-	-
Ni						1.0	.72	.75	-	.38	.34	.54	-	-.35	-	-
Co							1.0	.69	.31	-	.35	.58	-	-	-	-
Fe								1.0	-	-	-	.57	-	-	-	-
Mn									1.0	-	-	-	-	-	-	-
Ca										1.0	-	-	-	-	-	-
Mg											1.0	-	-	-	-	-
As												1.0	.42	-	-	-
Mo													1.0	-	-	-
U														1.0	-	-
Sn															1.0	-
W																1.0

CRITICAL VALUES OF ρ:
95% CONFIDENCE > .31
99% CONFIDENCE > .43

CLAST LITHOLOGY AND CHEMISTRY CORRELATIONS

Red Sedimentary clasts - Mg (-.45)

are significant because these elements behave differently in the secondary environment. In acidic groundwater conditions Zn is readily oxidized to a sulphate and mobilized in solution whereas Pb sulphate has a low solubility and Pb-Zn are not co-precipitated.

Anomalous Ag levels are present in Eatonville Till samples overlying both the Boss Point Formation and the Pictou Group sedimentary rocks (Fig. 10). Pictou Group rocks host a Cu-Ag and a U-Cu-Ag mineral occurrence about 6 km west of the Ag till anomalies (Chatterjee, 1983). Silver is not associated with other elements analyzed, including scavenging elements like Fe and Mn (Table 3b). The spatial relationship of these Ag anomalies to known Ag occurrences and the lack of correlation with scavenging elements suggest that the Ag anomalies are significant and may indicate new Ag mineral occurrences.

One Eatonville Till Cu anomaly (269 ppm) is near a Cu-Pb-Fe mineral occurrence near Limerock (Figs. 7 and 10). A second Eatonville Till Cu anomaly (1565 ppm) is located near River John about 5 km north of the aforementioned Cu-Ag occurrence. Two nearby samples have anomalous levels of Cd. These may be displaced anomalies

due to northward glacial dispersal or the result of an unknown Cu occurrence.

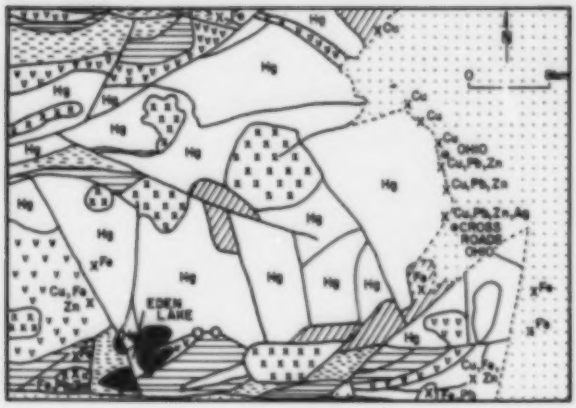
Copper values in Eatonville Till samples are weakly correlated with Co (0.34) and do not correlate with Fe or Mn (Table 3b). This suggests that scavenging processes from Fe-Mn sesquioxides in the clay fraction of the Eatonville Till have little influence on Cu levels. Copper is positively correlated with Mn (0.60) in the Toney River Till and the single Cu anomaly observed in this till may be concentrated by Fe-oxide co-precipitation (Table 3a; Fig. 10).

Till samples overlying most of the Cu mineral occurrences have background or below-background Cu levels (generally below the mean). The preponderance of low Cu values in this region was explained by Stea et al. (1986) as a result of Cu depletion in host rocks adjacent to mineral deposits.

Ohio

The Ohio study area (about 730 km^2) encompasses the central portion of the Antigonish Highlands. This highland region has a complex geology predominantly consisting of Precambrian metavolcanics and metasediments, unconformably overlain by Lower Paleozoic strata (Murphy, 1984). East of the Antigonish Highlands Devono-Carboniferous evaporitic and clastic sedimentary rocks predominate (Fig. 11).

Several stratiform Cu-Pb-Zn mineral occurrences (Ohio-Sylvan Glen copper belt) are located at the contact between Windsor Group carbonates and Horton Group conglomerate (Fig. 11; Bourque, 1981; Chatterjee, 1983). Copper minerals include malachite, chalcopyrite, chalcocite and/or bornite, and azurite. Lead and zinc occur as galena and sphalerite. To the west an unconformity separates Windsor Group carbonates and Keppoch Formation metavolcanics. The Cross Roads Ohio Cu-Pb-



Devono-Carboniferous

clastic and evaporitic sedimentary rocks

Silurian

Ross Brook Formation
blue-grey shale and siltstone

Beech Hill Cove Formation
arkose, blue-green siltstone and rhyolite

Ordivician-Silurian

Bears Brook Formation
arkose, red conglomerate, shale, rhyolite, rhyolitic tuff and minor basalt

Precambrian

Keppoch and Moose River Formations
clastic sedimentary rocks, mafic and felsic volcanic rocks

Intrusives

Devono-Carboniferous

Precambrian or Cambrian

Eden Lake Complex
appinite, hornblend syenite, pegmatite and microgranite

X Cu, Pb Mineral Occurrences

Figure 11. General geology of the Ohio study area (geology is adapted from Murphy, 1987).

Zn-Ag occurrence is hosted by rhyolitic lithic tuff of the Keppoch Formation (Fig.11). Mineralization occurs as fracture fillings in a secondary breccia stockwork. No silver minerals have been identified but Ag values are reported at 0.5 oz./ton (K. Northcote, personal communication, 1987). Murphy (1984) identified small, stratabound pyritic zones with traces of copper minerals occurring within the rhyolitic tuffaceous member of the Keppoch Formation. The regional 95th percentile contours identify coincident surface till anomalies of W-Ag-Zn-Cd overlying volcanic and granitoid rocks in the centre of the Antigonish Highlands and a Cu-Ag anomaly near the Cross Roads Ohio mineral occurrence (Fig. 12).

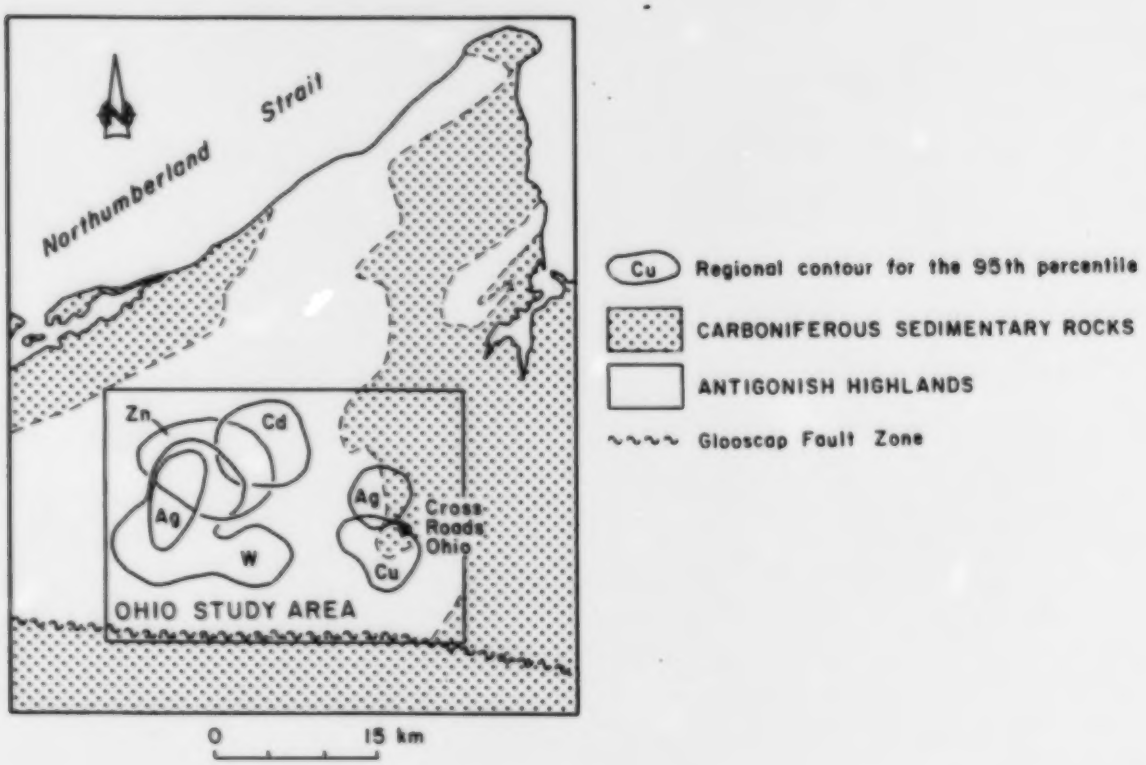


Figure 12. Regional 95th percentile contour of Cu, Zn, Ag and W data for the Ohio study area. Percentile values are derived from the total data set (n = 941; Table 1).

Two major till types, the Eatonville Till and an unnamed, locally-derived, stony till, were sampled in the area. Mean or background values for Ag, Cu, Zn and W are higher in the stony till compared to the Eatonville Till and to the regional till data set (Table 1). Background levels of Sn and Pb do not differ between these till units (Table 1). The stony tills also have significantly higher threshold levels for Ag, Cu, Zn and W compared to the local Eatonville Till and regional threshold levels (Table 1). The Eatonville Till has higher levels of Zn and Sn and similar levels of Ag and W compared to the corresponding regional threshold levels. Local threshold levels of Pb and Cd are lower than regional levels in both till types (Table 1). Element levels in the stony till are

probably elevated because of local dispersal from the Ohio-Sylvan Glen base metal mineral occurrences. The sandy matrix in these tills is more susceptible to hydromorphic concentration than the clay-rich matrix in the Eatonville Till. Element levels may increase by co-precipitation of base metals with weathering related Fe-Mn oxides.

Levels of Cu, Pb and Zn are positively correlated with Fe and/or Mn levels in both the Eatonville and stony tills. Fe or Mn sesquioxides may enhance levels of these elements (Table 4), but the relatively close spatial relationship of Cu-Pb-Ag anomalies to a known base metal belt implies that these anomalies are significant. Strong positive correlations between Pb and Zn in the Eatonville Till (0.64) and the stony till (0.80) also suggest that the base metal anomalies are significant.

Table 4a. Spearman rank correlation coefficients for Eatonville Till samples (n=27) in the Ohio study area.

SPEARMAN RANK CORRELATION COEFFICIENTS

OHIO (Eatonville Till)
(n = 27)

	Ag	Cu	Pb	Zn	Cd	Ni	Co	Fe	Mn	Ca	Mg	As	Mo	U	Sn	W
Ag	1.0	-	-	-	-	-.53	-	-	-	-	-	-	-	-	-	-
Cu		1.0	.55	.39	.33	-.40	.53	.41	.77	-	.47	-	-	-	-	-
Pb			1.0	.64	.33	-.40	.36	.53	.39	-	-	-	-	-	-	-
Zn				1.0	-	-.34	-	.45	-	-	.40	-	-	-	-	-
Cd					1.0	-	-	-	-	-	-	-	-	-	-	-
Ni						1.0	-	-	-.37	-	-.40	.32	-	.38	-	-.39
Co							1.0	.49	.69	-	-	-	-	-	-	-
Fe								1.0	.32	-	-	-	-	-	-	-
Mn									1.0	-	.53	-	-	-	-	.36
Ca										1.0	.37	-.32	-	-	-	-.37
Mg											1.0	-.49	-	-.45	-	-
As												1.0	-	-	-	-
Mo													1.0	-	-	-
U														1.0	-	-
Sn															1.0	.34
W																1.0

CRITICAL VALUES OF p:
95% CONFIDENCE > .32
99% CONFIDENCE > .45

CLAST LITHOLOGY AND CHEMISTRY CORRELATIONS
(n = 10)

CRITICAL VALUES OF p:
95% CONFIDENCE > .56
99% CONFIDENCE > .75

Red Sedimentary clasts	- As	(.72)	Felsic Volcanic clasts	- Zn (.56)
Grey Sedimentary clasts	- As	(.73)		- Ni (-.60)
Syenite clasts	- Ag	(.84)		- As (-.85)
	- Cd	(.64)		- Sn (.63)

Table 4b. Spearman rank correlation coefficients for stony till samples (n=21) in the Ohio study area.

SPEARMAN RANK CORRELATION COEFFICIENTS

OHIO (Stony, Grey Till)
(n = 29)

	Ag	Cu	Pb	Zn	Cd	Ni	Co	Fe	Mn	Ca	Mg	As	Mo	U	Sn	W
Ag	1.0	-	-	-	-	-	-	-	-	-	-	-	.60	.34	-	-
Cu		1.0	.38	.39	-	-	.57	-	.39	.40	.54	-	.38	-	-	-
Pb			1.0	.80	.53	-	-	-	.48	.38	.33	-	-	.34	-	-
Zn				1.0	.53	-	-	.36	-	.32	.50	-	-	-	-	-
Cd					1.0	-	-	-	.45	.35	.39	-	-	-	-	-
Ni						1.0	-	-	-	-	-	-	-	-	-	-
Co							1.0	.34	.60	-	.33	-	-	-	-	-
Fe								1.0	-	-	-	-	-	-	-	.39
Mn									1.0	.40	.47	-	-	-	-	.35
Ca										1.0	.69	-	-	-	-	-
Mg											1.0	-	-	-	-	-
As												1.0	-	-	-.33	-
Mo													1.0	.57	-	-
U														1.0	-.33	-
Sn															1.0	.48
W																1.0

CRITICAL VALUES OF p:
95% CONFIDENCE > .32
99% CONFIDENCE > .45

CLAST LITHOLOGY AND CHEMISTRY CORRELATIONS
(n = 16)

CRITICAL VALUES OF p:
95% CONFIDENCE > .43
99% CONFIDENCE > .60

Red Sedimentary clasts	- W	(-.60)	Syenite clasts - Cu (.58)
Grey Sedimentary clasts	- Cu	(-.45)	- Fe (.48)
	- Mg	(-.49)	Felsic Volcanic clasts - Mo (-.47)
Metamorphic clasts	- Ca	(.44)	- W (.46)
Granite clasts	- Cd	(.44)	Mafic Volcanic clasts - Ca (.45)
	- Ca	(.52)	- Mg (.73)
	- Co	(-.45)	Volcaniclastic clasts - Co (-.89)
			- Fe (-.65)

One anomalous Ag value in the clay fraction of the stony till is located about 2.5 km north of the Cross Roads Ohio Cu-Pb-Zn-Ag occurrence and a halo of Cu-Pb-Zn-Cd anomalies extends 5-10 km south-southwest from this base metal belt (Fig. 13). These anomalies may be a result of southward dispersal from the mineral occurrences or may identify areas of new mineral potential. Other Cu-Pb-Zn-Ag anomalies are present in till overlying volcanics of the Keppoch and Beech Hill Cove Formations, about 5 - 20 km west of the known mineral showings, near Middle Barneys River. These anomalies may indicate the presence of new base metal mineral occurrences hosted by volcanic rocks, as in the Keppoch Formation at Cross Roads Ohio.

Anomalous levels of tungsten were also found in three samples from the Middle Barneys River area, coincident with the base metal anomaly association. Tungsten

is positively correlated with felsic volcanic clasts (0.46) in the stony till and tin is positively correlated with felsic volcanic clasts (0.63) in the Eatonville

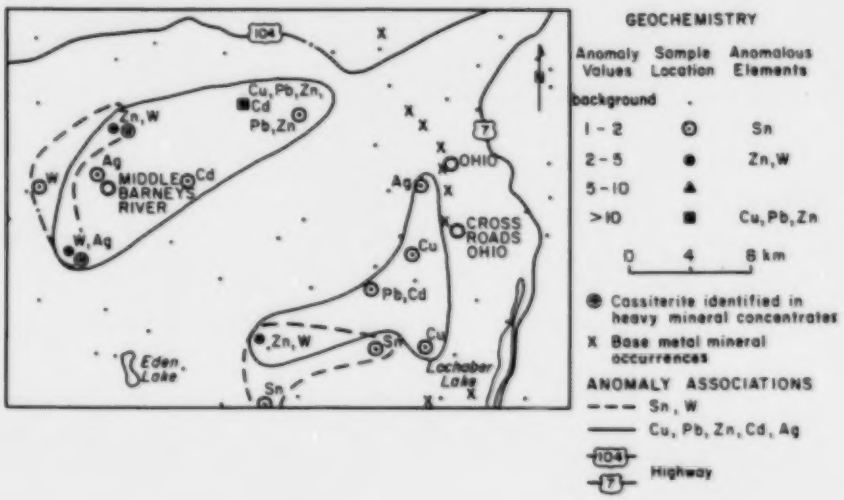


Figure 13. Anomaly association map of the Ohio study area.

Till (Table 4). These Sn-W anomalies and coincident base metal anomalies may reflect an undiscovered polymetallic mineral occurrence hosted by volcanic rocks.

Cassiterite was identified (by S.E.M.) in stony till samples with anomalous W levels and below-threshold Sn levels (Fig. 13; Plate 2). Tungsten minerals were

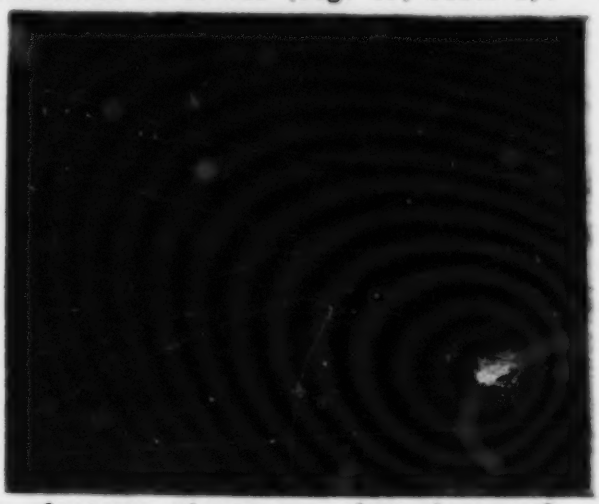


Plate 2. Scanning electron microscope photomicrograph of a cassiterite grain identified in a heavy mineral concentrate from a stony till sample collected near Middle Barneys River.

not identified in heavy mineral concentrates from the anomalous samples. This may be a result of the nugget effect. The two highest tin values occur in both the Eatonville and stony tills overlying volcanic rocks near the southern boundary of the study area. Tin is correlated with W in both the Eatonville (0.34) and stony tills (0.48).

A possible Nova Scotia analogue for base metal and W mineralization hosted in volcanic rocks occurs in the Cape North area of Cape Breton Island, (Fig. 1). About 35 minor polymetallic and related mineral showings were mapped by Macdonald and Smith (1980). The majority of these were hosted by Hadrynian volcano-sedimentary rocks of the Money Point Group including: metavolcanic schists, metatuff, metarhyolite, metabasalt and metasedimentary schists, or within and adjacent to granitic plutons. Mineralization (pyrite, pyrrhotite, marcasite, chalcopyrite and sphalerite) occurs in graphitic schists. The close association of mineralization to the graphitic and metavolcanic schists of the Money Point Group suggests a volcanogenic-sedimentary origin (Macdonald and Smith, 1980). Minor amounts of fine grained sulphides occur as irregular disseminations adjacent to rusty quartz seams and veins at several localities within the Money Point Group (Macdonald and Smith, 1980). Sulphides include pyrite, pyrrhotite, chalcopyrite, sphalerite and galena. Tungsten mineralization in this volcanic-sedimentary environment is indicated by a stream geochemical survey (Reimann, 1983) that revealed numerous W anomalies in the Cape North area. Scheelite (ranging from 0 to 101 grains) was identified in 40-50 kg stream sediment samples concentrated using a 'Goldhound' automatic panner. The source of these scheelite anomalies was not found but they occur preferentially in streams draining the Money Point Group (Reimann, 1983).

The till anomalies and mineral occurrences described at Ohio and Cape North are related to metavolcanic rock suites. A second possible analogue is Archean

submarine volcanic exhalatives hosting stratabound scheelite and associated base metal mineral occurrences in western Greenland (Appel, 1986).

CONCLUSIONS

The significance of till anomalies can be assessed by using both regional and local element levels. Regional levels, based on the entire data set, tend to be lower for most elements than local threshold levels, based on till types, because of dilution from large areas of geochemically flat bedrock. However, large areas of single-element anomalies were outlined using the 75th and 95th percentile contours from the regional data set. Local case studies (Wentworth Station, Scotsburn and Ohio) were selected from these regionally contoured areas. Local thresholds were calculated based on lithologically and texturally defined till types. Anomaly patterns identified using the local threshold are coincident with anomalies from the regional till data set. However, they are sharpened to narrow belts that are a closer reflection of the presumed source areas. The significance of the local case study till anomalies can be interpreted by using the following methods:

(1) Multi-Element Approach

This approach compensates for below-threshold but significant element levels by revealing anomalies in associated elements that are related to mineralization. Many till anomalies identified in this study are coincident with known mineral occurrences. The Wentworth Station and Scotsburn study areas illustrate that till geochemistry highlights areas of mineralization. Areas of exploration interest can be identified by grouping samples containing anomalous elements within each anomaly association (for example, Zn-Ag-W and Cu-Pb-Zn-Ag mineral potential overlying volcanic rocks of the Antigonish Highlands).

(2) Inter-Element Correlations

Strong correlations with scavenging element species such as Fe or Mn may suggest false or nonsignificant anomalies. Primary metal associations such as Cu-Pb-Zn suggest significant anomalies. This is shown by Pb-Zn correlations in the Eatonville Till from the Scotsburn and Ohio study areas. These elements behave differently in the secondary environment. In acidic groundwater conditions Zn is readily oxidized to a sulphate and mobilized in solution whereas Pb sulphate has a low solubility. It is unlikely that these elements would be concentrated together by scavenging.

(3) Clast-Element Correlations

Strong element correlations with clast geology may identify bedrock source targets for the till anomalies. Eatonville Till and regolith samples collected in the Wentworth Station study area show a positive correlation of Sn and W with granitic clasts. These correlations imply that granitic rocks of the area host Sn-W minerals. Cassiterite is known to occur in the Byers Brook Formation mafic volcanics.

Zinc is strongly correlated with grey sedimentary clasts (0.91) in the Toney River Till and a strong correlation exists for Pb and Zn. Till samples with the highest Pb-Zn anomalies occur near the contact of the Boss Point Formation sediments and the Millsville Formation conglomerate. These correlations suggest that the till anomalies are related to mineralization hosted by the Boss Point Formation.

Felsic volcanic rocks of the Antigonish Highlands region may host Sn and/or W minerals. Tungsten is positively correlated with felsic volcanic clasts in the stony till and tin is positively correlated with felsic volcanic clasts in the Eatonville Till (Table 4). Cassiterite was identified in stony till samples with anomalous W levels.

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